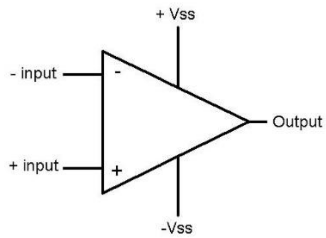
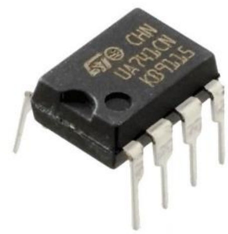
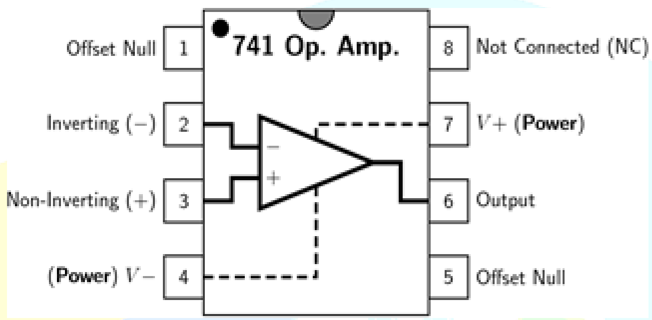
## (2) Operational amplifier:



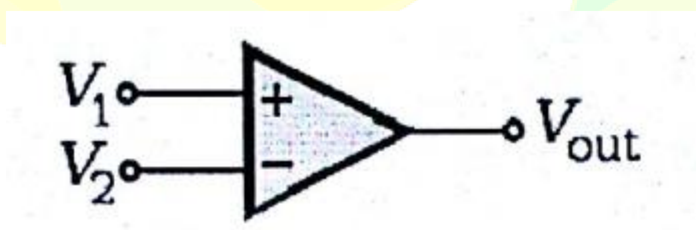






**<u>Operational Amplifiers</u>, or <u>Op-amps</u> as they are more commonly called, are one of the basic blocks of Analogue Electronic Circuits. Operational amplifiers are linear devices that have all the properties required for nearly ideal DC amplification and are therefore used extensively m signal conditioning, filtering or to perform mathematical operations such as add, subtract, integration and differentiation.**

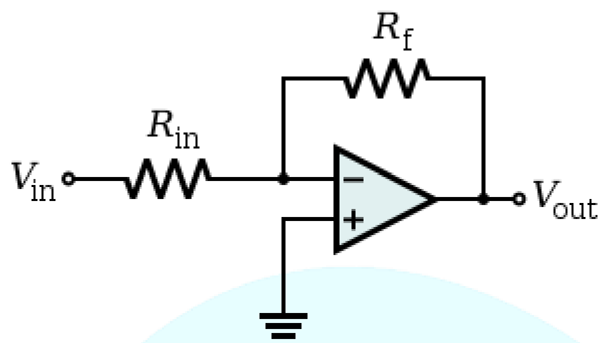
### Applications:

1. Comparator



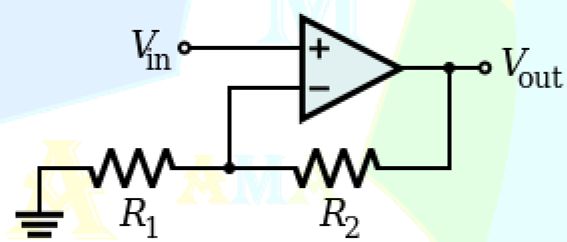

$$V_{out} = \begin{cases} V_+ & \text{if } V_1 > V_2 \\ V_- & \text{if } V_2 > V_1 \\ 0 & \text{if } V_1 = V_2 \end{cases}$$

2. Inverting amplifier



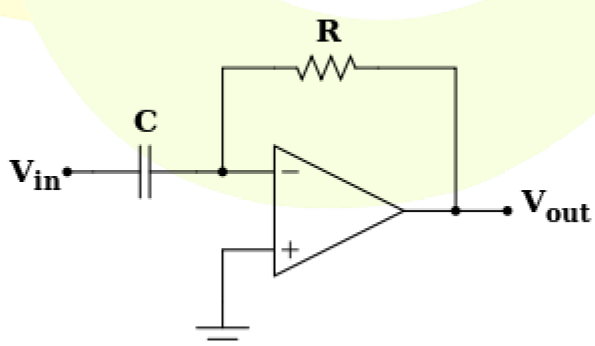

$$Vout = -\frac{Rf}{Rin}\, Vin$$

3. Non-inverting amplifier



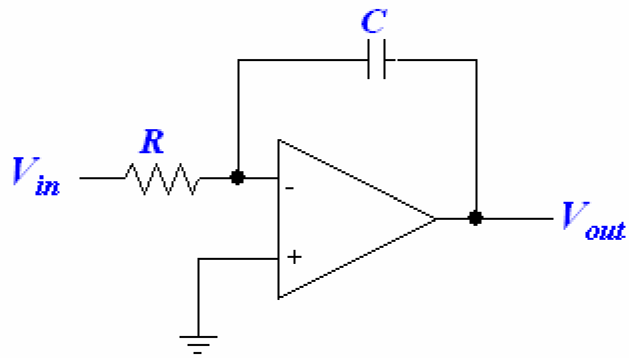

$$Vout = \left(1 + \frac{R2}{R1}\right) Vin$$

4. Differentiator



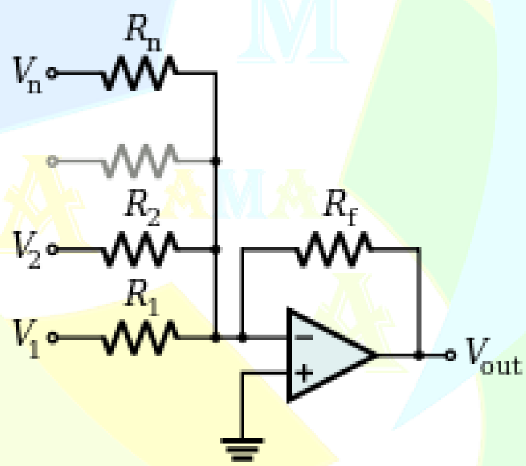

$$Vout = -RC\,\frac{dVin}{dt}$$

5. Integrator




$$Vout = -\int_0^t \frac{1}{RC} Vin \; dt + Vinitial$$

6. Summing amplifier



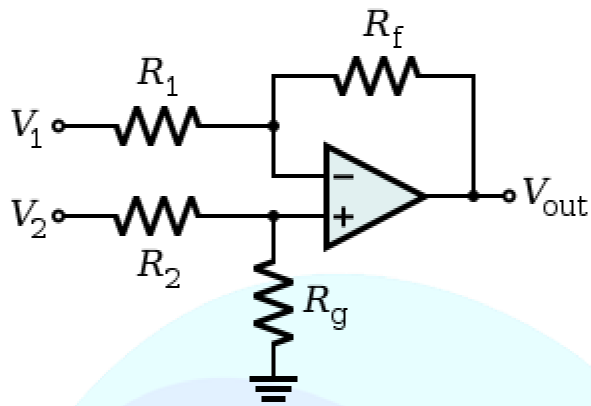

$$Vout = -\frac{Rf}{R1} V1 - \frac{Rf}{R2} V2 - \ldots\ldots\ldots - \frac{Rf}{Rn} Vn$$

$$Vout = -Rf \left( \frac{V1}{R1} + \frac{V2}{R2} + \ldots\ldots\ldots + \frac{Vn}{Rn} \right)$$

$$if\ we\ choose\ R1 = R2 = \ldots\ldots\ldots = Rn$$

$$Vout = -\frac{Rf}{R1} \left( V1 + V2 + \ldots\ldots\ldots + Vn \right)$$

### 7. Difference amplifier




$$Vout = \frac{Rg}{R2}\,V2\ - \frac{Rf}{R1}\,V1$$

$if\ we\ choose\text{:}\ R1 = R2 \text{ and } Rf = Rg$

$$Vout = \frac{Rf}{R1}\,(V2\ - V1)$$